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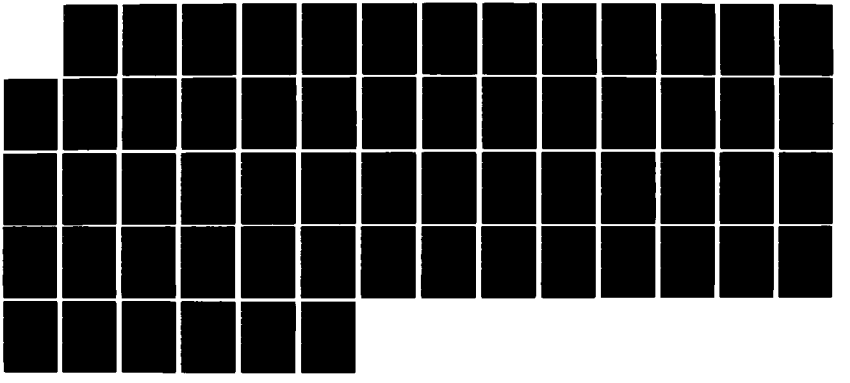

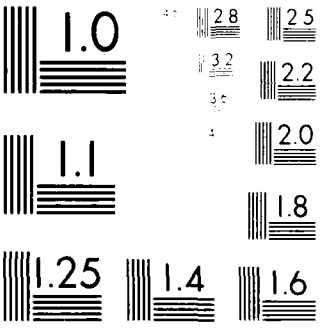
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PROMOTING QUALITY IN NAVFAC CONSTRUCTION

BY

ROBERT D. ROTZ

A REPORT PRESENTED TO THE GRADUATE COMMITTEE
OF THE DEPARTMENT OF CIVIL ENGINEERING IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF ENGINEERING

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To my wife, Kristie

and daughters, Rebecca and Jennifer

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KEY TO SYMBOLS OR ABBREVIATIONS

ACI	American Concrete Institute
AGC	Associated General Contractors
ASCE	American Society of Civil Engineers
ASTM	American Society of Testing Materials
A/E	Architect/ Engineer
AFRCE	Air Force Regional Civil Engineer
AROICC	Assistant Resident Officer in Charge of Construction
BCE	Base Civil Engineer
BEQ	Bachelor Enlisted Quarters
CAD	Computer Aided Design
CBD	Commerce Business Daily
CEC	Civil Engineer Corps
CECOS	Civil Engineer Corps Officer School
CO	Commanding Officer
Code 02	Contract Division
Code 04	Design Division
Code 09A1	Acquisition Coordination Officer
CONREP	Construction Representative
CQC	Contractor Quality Control
CQC+	Contractor Quality Control Plus
DCAA	Defense Contracting Audit Agency
DOD	Department of Defense
EEO	Equal Employment Opportunity
EFD	Engineering Field Division
EIC	Engineer in Charge
ESR	Engineering Service Request
FAR	Federal Acquisition Regulations
FY	Fiscal Year
NAVFAC	Naval Facilities Engineering Command
NAVFACENGCOM	Naval Facilities Engineering Command
NCIS	Navy Construction Inspection System
OFCC	Office of Federal Contract Compliance
OIC	Officer in Charge
PM	Project Manager
PWO	Public Works Officer
QA	Quality Assurance
QC	Quality Control
ROICC	Resident Officer in Charge of Construction
SCE	Staff Civil Engineer
SF	Standard Form
SOUTHDIV	Southern Division, Naval Facilities Engineering Command
SOUTHNAVFACENGCOM	Southern Division, Naval Facilities Engineering Command
USN	United States Navy

CHAPTER I

INTRODUCTION

From the initial stages of a Navy construction project, quality does not drive the design-construction system but is only achieved within the constraints of meeting budget authorizations and time schedules. This unfortunate circumstance is an inherent problem in the federal budget and legislative processes. Following the flow of procurement authorizations and appropriations, a period of two to ten years may lapse from the time that the need for a facility is first identified until construction actually commences. During this time frame, the need for the new facility grows acutely.

From the moment the architect/ engineer (A/E) Selection Board makes its decision, the press is on to finish the project within budget and with no or minimal delays. Great potential exists for waste to occur, excessive construction costs to accrue, and client commands to be left with a less than quality facility. Quality is sacrificed for meeting a schedule or budget.

Quality is too important to be left to chance or to be a possible byproduct of meeting a schedule or budget. Doing the job right the first time can save time and money as it eliminates the need for rework. Emphasizing total quality

management in both the design phase and the construction phase of a project can improve acceptance and appreciation by client commands, reduce the cost of administering the project, and reduce the life cycle cost of the project.

Is the effort put forth by the Naval Facilities Engineering Command (NAVFACENGCOM or NAVFAC) toward quality construction effective or is it another layer of paper work? This analysis will highlight some of the problem areas in NAVFAC construction quality control and offer or explore possible alternatives.

CHAPTER II

QUALITY IN DESIGN

The pursuit of quality construction must begin as early in the procurement process as possible. With regards to total life cycle costs for a facility, the smallest cost is expended by the designer whose decisions make the greatest impact on costs. For example, in examining the costs of a typical Bachelor Enlisted Quarters (BEQ) with a total useful life of 25 years, it has been estimated that 56% of the life cycle cost can be attributed to outfitting, operating, maintenance, and repair costs. Construction costs represented 42% and only 2% go toward design. [Iselin, p.37] Although the design fees are a relatively minor portion of the costs, the design effort plays a tremendous influence on the remaining life cycle costs. A high return on investment can be expected when resources are set aside for proper quality management during the design process.

Selection Process

The first area that should be explored is the designer selection process itself. Only about 12% of the design work is done in-house by civilian employees or Navy intern architects. [J.C. Doebler, personal communication, 27 May 1986] That leaves the bulk of the design effort to be contracted by architect/ engineer (A/E) firms.

The federal government is the largest single client of architectural and engineering professionals. The Department of Defense (DOD) is the leading agency in making A/E awards. For fiscal year (FY) 1983, 1884 contracts totaling $206,834,000 were awarded for procurement of A/E services by the Navy. [CECOS, lesson 2250-1, p. 1] The trend is that the number and dollar value of A/E contracts per year is increasing.

A/E selection is controlled primarily by public laws, the Federal Acquisition Regulations (FAR), and the Department of Defense FAR Supplement. Additional direction is provided by the NAVFAC Contracting Manual (P-68), which defines the commands' authority and responsibilities and sets internal procedures and delegations of authority. Local Engineering Field Division (EFD) policies and procedures may differ for each of NAVFAC's six geographical EFDs.

A/E firms are selected to perform government design work on the basis of their qualifications and capabilities as they relate to the proposed project. Public Law 92-582, (40 USC 541-544) Amending the Federal Property and Administrative Services Act of 1949, or commonly referred to as the Brooks Bill, sets this policy. Under this system, design requirements for proposed construction projects are synopsized and announced to the public. If the designer's

fee is expected to exceed $10,000, the project is announced in the Commerce Business Daily (CBD), otherwise, public notice at the contracting office is sufficient. The synopsis gives a general description of the project including what it is, how big, time limits to be imposed, and significant selection criteria to be used.

Examples of A/E selection evaluation criteria may include:

1. Qualifications of people to do the work
2. Recent experience of these people in the specific skills required for this project
3. Quality assurance and bid document coordination methods used during design
4. Awards from all DOD agencies in the last five fiscal years
5. Ability to do the work within the time frame allowed
6. Distance from the project
7. Cost control methods used during design and construction bidding record (low bid vs. estimate)
8. Past experience on DOD contracts
9. Ability to do construction inspection

A/E firms desirous of the contract are to submit their qualifications using Standard Forms (SF) 254 and 255. The SF 254 is a general resume of the firm's experience. It will be maintained on file with the contracting officer and

should be updated periodically by the A/E firm. Standard Form 255 states the A/E's specific qualifications for the particular contract.

After allowing an appropriate time for submissions, usually 30 days, the procuring activity ranks the A/Es in order of their qualifications to perform the proposed project using a two step process. A board of three or more professional personnel is used to consider the qualifications of interested A/E firms and to develop a slate of firms for further consideration. A separate board considers the qualifications of these firms in great detail and conducts interviews (in person or via telephone) to evaluate technical competence. Based on this board's evaluation, a selection list of three or more firms in order of priority is developed, with the firm considered to be most qualified at the head of the list.

The proceedings of the boards are carefully documented and their actions are subject to higher level review and approval, depending on the size of the contract.

After the A/E selection is approved, the A/E is provided a description of the scope of work and requested to submit a fee proposal. The fee proposal is an offer from the A/E to perform the services described in the statement of services for a fixed price. The proposal must contain a detailed statement of the A/E's and proposed consultant's

estimated costs together with an allowance for profit. This proposal is usually a breakdown of direct labor hours, labor rates, material, subcontracting costs, overhead, and profit. The direct costs are further subdivided by disciplines of design and proposed personnel. In accordance with 10 USC 7212, the fee for A/E design services may not exceed 6% of the estimated cost of the project to which the fee applies.

Negotiations are entered into with the firm and, if an agreement is reached on a fair and reasonable fee, a contract is awarded. Should the most qualified A/E be unwilling to perform the prospective services at a fair and reasonable fee, negotiations are discontinued. The procuring agency must then negotiate with the next ranking firm, and so on, until the most qualified firm is found who will perform the work at a fee fair and reasonable to the government.

Some administrative details in the A/E selection process have not been discussed; however, Figure 1 provides a Flow Chart for A/E Selection, Negotiation and Award Process.

Quality Designer

Numerous procedural safeguards ensure that A/E selection is conducted fairly and honestly. However, is the A/E firm selected the most qualified for the project?

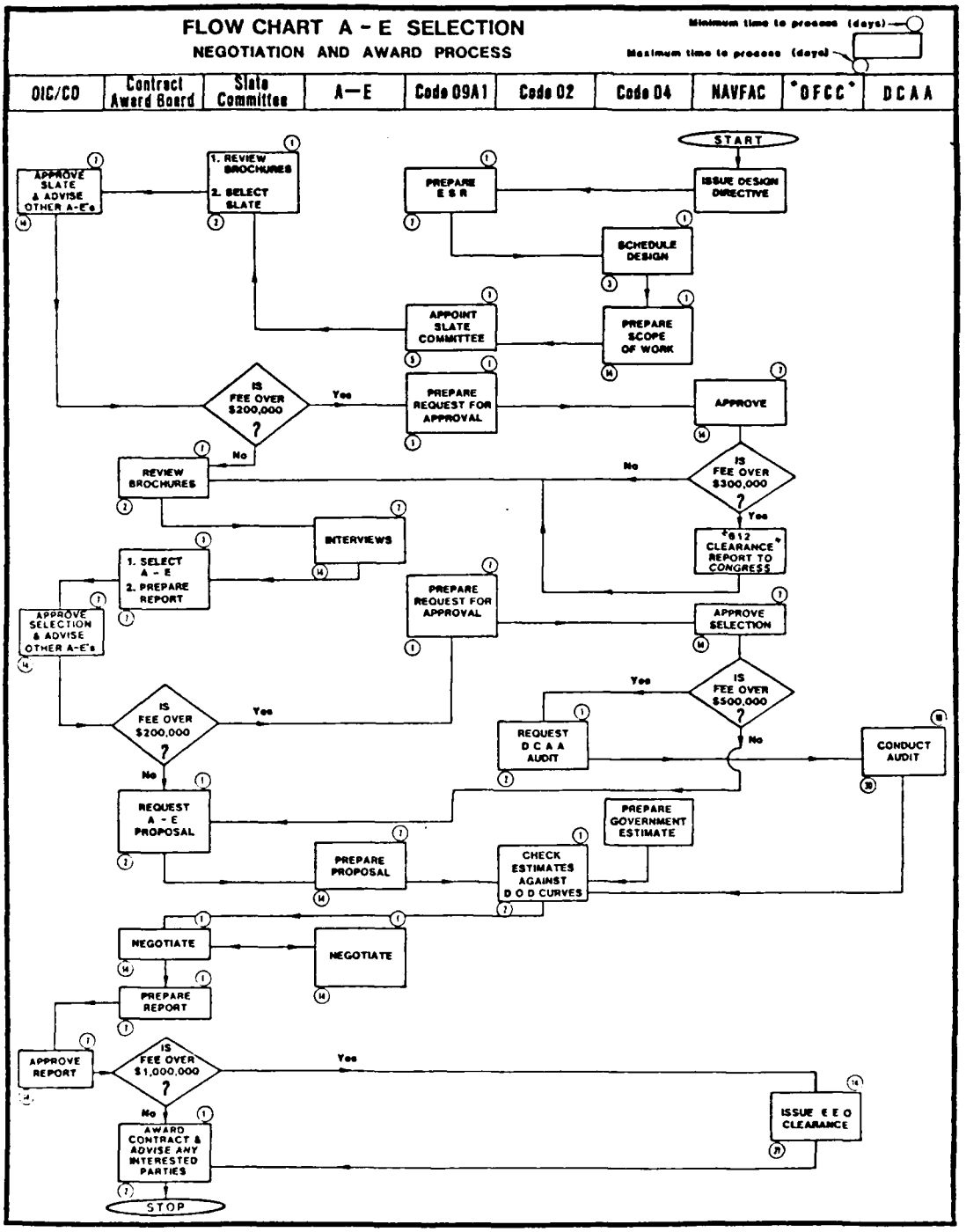

Figure 1 - Flow Chart for A/E Selection, Negotiation, and Award Process

(Reproduced from CEGS, Section 01201, p. 1)

Special Considerations

Although the objective of the selection process is to identify the A/E which best meets a list of objective criteria based on the qualifications and past performance of the firm, some unqualified influence may enter the selection process. Special consideration must be given to "spreading the work" by bringing in new (no awards in the last five fiscal years) and minority A/E firms. Each slate committee must ensure that new and minority firms are treated fairly. Each Officer-In-Charge (OIC) must have procedures to monitor awards to new and minority firms. There is a Minority 8A Program (A/E) that can be used to stimulate minority contracting.

Firms having DOD awards of $500,000 or more in the prior fiscal year or substantially more in the prior two fiscal years normally require additional justification if they are to be recommended. Additionally, so far as practicable, firms recommended should be from the area where the work is located, i.e. within the state.

These requirements are dictated by the FAR, DOD, and NAVFAC policy. Congressional watchdogs stand ready to pounce on irregularities. Yet, these requirements may tend to be counterproductive to the Brooks Bill and may provide cause for the most qualified firm to be disqualified.

Public Relations Front

The selection process itself can be unknowingly swayed in deciding the most competent A/E firm for the project. A well concerted public relations effort by the A/E in preparing the SF 254 and 255, as well as a subsequent interview, could paint a glowing facade to slate and selection board members. Many larger A/E firms are hiring professional marketing talent as part of their in-house organization to improve their firm's image.

Following revisions to the ethical codes of the American Institute of Architects and the National Society of Professional Engineers, some A/E firms are availing themselves of outside marketing organizations. Such organizations monitor the construction programs of federal agencies. With all relevant information on a specific construction project in hand, the outside marketing organization assists the A/E in structuring their SF 254 and 255 to be fully responsive to the design requirements and addressing each of the selection criteria.

Upon receiving an invitation to be interviewed, the marketing organization further assists the client A/E in structuring its presentation. Visual graphics are prepared and A/E personnel are coached on delivery format that addresses criteria believed to be used by the selection board.

Should the A/E client be selected, additional assistance is provided in preparing the fee proposal and in negotiating the contract. Throughout the life of the contract, other services may be provided as necessary, such as counsel or tracing late payments of invoices. In such an instance, has technical competition succeeded or is it a battle between public relations firms?

Designer Fees

The designer's fee is not used as criteria in determining the most qualified A/E firm. As indicated earlier, it is not until the A/E firm has been selected on technical competence that the firm is directed to provide a fee proposal, and the design component of that proposal, by law, may not exceed 6% of the estimated cost of the project.

The authority given by the statutes is clear but the extent of the 6% fee limitation and the costs to which the fee limitation applies are not as obvious from a literal reading of the statute. It is misleading and incorrect to assume that the 6% limitation applies to the A/E's total fee. It only applies to the actual design costs (i.e. working plans and specifications plus overhead and profit) as opposed to costs for engineering services (e.g. submittal review, as-built drawing preparations, interior design,

construction consultation, travel, site investigation, or other special costs).

Following the general outline of Figure 2, SOUTHNAVFACENGCOM A&E Fee Proposal (format may vary between EFD's), negotiations are conducted between the selected firm and the government to arrive at a fair and reasonable fee. Since the 6% fee limitation only applies to Design Section A, an invitation exists for the A/E to carry excess design costs (costs that would cause the proposal to exceed the 6% limitation) to the reverse side of Figure 2 and conceal these excesses as, for instance, Other Special Costs under Engineering Services. This action may become more prevalent when differences exist between the fee proposal and the government estimate and undue pressure exists on the government to meet deadlines (i.e., 35% design prior to the Presidential budget submission, or FY fourth quarter push). Although compliance with the 6% fee limitation is technically met, the intent of the law is circumvented and the negotiated fee may not be fair and reasonable or in the best interests of the government. The system allows inefficiencies of the firm to be financed by the government.

Alternate Selection Process

The procedures described for the selection of an A/E firm have been applied for more than 45 years. Some changes

A&E FEE PROPOSAL
SOUTHNAVFACENGCOM 11012/TF-1 (10/75)

THIS INFORMATION IS REQUIRED TO EVALUATE FEE PROPOSALS AND COMPLY WITH NAVY AUDIT REQUIREMENTS ON NEGOTIATED CONTRACTS

NAME AND ADDRESS

PROJECT TITLE

LOCATION	CONTRACT NUMBER	EST COST OF CONSTRUCTION

		NO OF DRAWINGS	EST NO OF HOURS	HOURLY RATE	TOTAL ESTIMATED COST BY A&E (A)	TOTAL ESTIMATED COST BY CONSULTANT (B)
1 DRAWINGS	A PROJECT ENGINEER					
	B ARCHITECT					
	C STRUCTURAL ENGINEER					
	D MECHANICAL ENGINEER					
	E ELECTRICAL ENGINEER					
	F CIVIL ENGINEER					
	G LANDSCAPE ARCHITECT					
	H OTHER (SPECIFY)					
	I DRAFTSMEN (1) ARCHITECTURAL					
	(2) STRUCTURAL					
	(3) MECHANICAL					
	(4) ELECTRICAL					
	(5) CIVIL					
	(6) OTHER (SPECIFY)					
	TOTAL - DRAWINGS					
2 SPECIFICATIONS	A SPECIFICATION WRITERS					
	B TYPIST					
	TOTAL - SPECIFICATIONS					
3 REPORTS	A ENGINEER					
	TOTAL DESIGN COST (ITEMS 1, 2, & 3)					
	OVERHEAD _____ % X $ _____ (TOTAL COLUMN A) =					
	PROFIT _____ % X $ _____ (TOTAL COLUMNS A & B + OVERHEAD) =					
	TRAVEL RELATED TO DIRECT DESIGN (SECTION E ON BACK) =					
	TOTAL FROM SECTION A CANNOT EXCEED 15% OF THIS AMOUNT → TOTAL SECTION A DESIGN					

Figure 2 - A&E Fee Proposal (front)

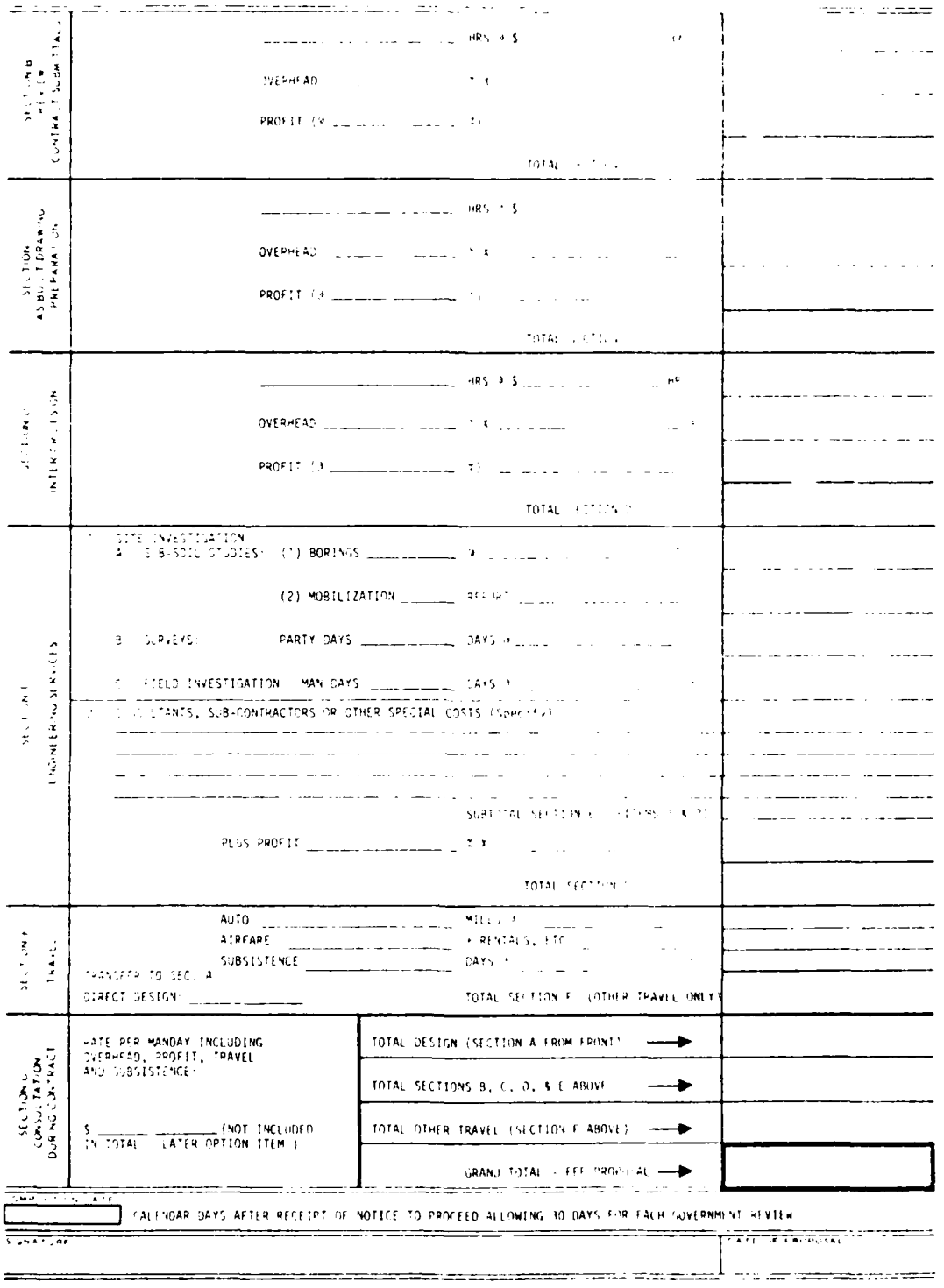

Figure [illegible] AAE Fee Proposal [illegible]

have occurred through law and through previous generations of the FAR (Armed Services Procurement Regulations and the Defense Acquisition Regulations) but the principles have remained the same. However, times have changed and budget cuts are common stories in the daily news. The Gramm - Rudman - Hollings Deficit Reduction Bill is having a serious impact on federal procurement. Efforts are being taken to trim excess from the budget and spend the federal dollar wisely. In DOD, efforts must be taken to get more construction for the dollar. It is time to resurrect some old and controversial ideas for A/E selection and in doing so, eliminate some inherent problems with the present system.

The idea to use price competition in the procurement of A/E services is not new. The Brooks Bill was enacted in direct response to this controversy. It was felt that to use price competition (bidding) as the basis for selection would attract A/E firms of less competence, or those that would not exercise reasonable care and skill in their design work. These firms could offer their services at a lower fee and maintain an unfair advantage in obtaining the contract. Quality would be compromised and this would equate to higher life cycle costs for the facilities. This may be true when price competition is the sole basis for A/E selection.

Mere technical competition in the selection of an A/E firm is not enough. As costs can be an indication of a firm's degree of organization and effectiveness which, in turn, can affect its quality of work, a system that combines technical competition and price competition should be adopted. Consider a two step selection process whereby the proposed construction project is announced in the Commerce Business Daily, as before. A/E firms desiring to be considered for the design contract submit their SF 254 and 255. After allowing an appropriate time for submissions, a slate board selects 3-5 firms for further consideration based purely on technical qualifications. Special considerations required under the present system would no longer apply. These firms will then receive a description of the scope of work and be requested to submit a fee proposal. Special attention must be given by the EFD in preparing a complete or comprehensive scope of work. The 6% fee limitation is repealed.

A separate selection board determines evaluation criteria (technical as well as fee) for the proposed project and assigns a weighting factor to each. Using this set of criteria, the selection board then considers the technical qualifications and fee proposals of these firms in great detail and conducts interviews. A list ranking the firms in order of priority is developed and once approved,

negotiations would be conducted should differences exist with the government price estimate.

What affects would this process have on quality? Technical competence would still be required by both the slate and the selection boards. Special considerations required under the present system would no longer disqualify competent firms or give any firms an unfair advantage. Professional marketing organizations could assist in finding the most qualified firm by matching the project to firms that might otherwise not have been qualified. Providing price competition at the selection board phase allows more efficient firms to gain an advantage and reduce direct costs yet still maintain a profit margin.

Implementation of this two step selection process would be no easy task. Proponents of the present system would argue that once price is introduced as a selection factor, in time it will become the selection factor. Without safeguards, this might be so; however, there are enough checks and balances in the approval process to prevent this from happening. Another argument against the proposed two step process is that the chance of an A/E firm being selected is already slim and the expense of providing a fee proposal to the selection board would deter A/E firms from applying for consideration. This can be rebutted by the fact that the federally contracted portion of all design

engineering services is too large to be ignored. Utilizing the proposed two step selection process, it is predicted that the quality of design work would improve and, at the same time, a cost savings would be realized by the government.

Quality Contract Documents

The A/E firm is under contract to provide the project plans and specifications. It is the A/E's responsibility to see that the design job is complete, using sound engineering principles, is of high quality, meets the requirements of the scope of work, and can be built for least cost. When quality plans and specifications are provided, contractors can develop more realistic and competitive bids as risks associated with design errors or omissions and ambiguous specifications would be eliminated.

Plans and specifications, though, are not perfect. Errors in drawings and specifications are the source of a significant number of change orders. For FY 85, construction contract change orders for SOUTHDIV relating to design errors or omissions represented approximately 14.8% of the total change orders and amounted to $4,837,037. [T. Yeager, personal communication, 27 May 1986] However, through organized quality control procedures, errors and omissions can be reduced to an acceptable level.

Design Reviews

Outside of any quality control (QC) measures that exist internal to the A/E firm, NAVFAC has instituted a series of design reviews to occur at various stages of the design process. These reviews involve the customer command for whom the facility is intended, the naval base Public Works Officer (PWO) or command Staff Civil Engineer (SCE), the Navy's Engineer in Charge (EIC) of the project, and the Resident Officer in Charge of Construction (ROICC). In situations where the customer command is the U. S. Air Force, the Navy PWO and SCE are replaced by the Base Civil Engineer (BCE) and design personnel from the Air Force Regional Civil Engineer (AFRCE).

Each participant in the design review process is to scrutinize the prepared plans and specifications for errors and omissions. A sample of areas to be checked include: confirmation that operational requirements are met, proper completion times set, verify existing conditions, coordination problems with other contracts, constructability review, value engineering review, and various administrative items. Comments are evaluated and incorporated into the final design before the plans and specifications receive final appr al.

Although the principles behind the NAVFAC design quality control measures are sound, some discrepancies

exist. Most customer commands do not have the technical expertise to comment on areas other than checking surface finishes and colors or the building layout. The PWO or SCE will verify the project scope against the needs, ensure conformity with the Base Master Plan, check energy and environmental needs, and check maintainability. The brunt of the design review rests with the ROICC and the EIC; however, these personnel frequently lack the technical expertise, time, or facilities to do a proper design review.

The typical ROICC office is composed of a senior officer as the ROICC and one or more junior officers and/ or civilian engineers as Assistant Officers in Charge of Construction (AROICC) or Project Managers (PM). These AROICCs and PMs come from various engineering disciplines, including fields such as systems or ocean engineering, and most may be working in construction for the first time. Their primary function is to be the Navy's representative to oversee and coordinate all phases of the construction contract from the time of award until a finished product is delivered. Construction Representatives (CONREP) carry out the government inspection of contracts. These people play a critical role in the review process; however, proper 90/100% design reviews repeatedly become a lower priority to the administrative and inspection loads of active construction contracts and are accomplished only as time permits.

To assist the inexperienced AROICC or PM in conducting proper design reviews, a system called REDICHECK was developed by Lieutenant Commander William T. Nigro, CEC, USN. REDICHECK provides a systematic approach to checking the designer's drawings and specifications for coordination errors between disciplines. It highlights various types of coordination errors frequently found. When used properly, it has saved from 1 to 3% of total construction costs. [Nigro, p. 3] When using REDICHECK, the use of a light table is strongly recommended to compare drawings between disciplines but few ROICC offices are afforded this luxury.

The EIC maintains a busy schedule while coordinating and managing the design efforts for an average of 10 to 12 projects. [J. Owens, personal communications, 27 May 1986] Typically, sufficient time does not exist to conduct proper quality assurance (QA) of the designer's plans, specifications and calculations.

Recently, NAVFAC established a Headquarter's Contracts Quality Assurance Division as a result of discrepancies identified during several inspections. The Division functions to:

1. Formulate policy and guidance relative to NAVFAC contract quality assurance

2. Develop efficient and effective procedures for

NAVFAC contract quality assurance and coordinate their implementation

3. Monitor NAVFAC contracting activities to identify contract quality assurance problems and develop appropriate solutions

4. Assure technical engineering advice and consultation are available to contracting officers in quality assurance matters

5. Determine procurement training required in NAVFAC contract quality assurance matters and oversee provision of such

6. Coordinate development and maintenance of NAVFAC publications and written guidance in the subject area of contract quality assurance

7. Coordinate development of staffing and training standards and standard organizations for NAVFAC contract quality assurance organizations

It is recommended that a similar Division be established at each EFD, and whose functions would be modifications of those listed above. This dedicated quality assurance group would also be tasked with EIC level design reviews. At the ROICC office, a similar group, composed of an AROICC or PM and a CONREP, each with sufficient technical and construction experience, would have the primary task of design reviews. As time permits, collateral duties may be

assigned. These people must have available the time and resources necessary to carry out their QA duties.

Should personnel constraints pose difficulties in establishing dedicated QA teams at the EFD and the ROICC offices, third party A/E peer review should be conducted. It has proven to be quite successful overseas. The third party A/E would be charged with conducting a constructability review and value engineering analysis. It would not redesign the project. As with the government's review, the third party A/E would assume no liability for the original design. The added expense of this type of review would be handsomely compensated by a sharp reduction in expenditures on construction change orders for design errors and omissions. This was a recommendation of an American Society of Civil Engineers Workshop on Quality in the Constructed Project conducted 13-15 November 1984. [Fox, Cornell, p. 154]

Lessons Learned

Lessons learned through the construction phase of one project are not incorporated into the design of a proposed project of similar construction. It is a perception in the ROICC office that design review comments are often ignored. After correcting design problems with the cable television distribution system in a BEQ project, the same incorrect

system was designed into two proposed, separate and distinct BEQ renovation projects. Often times, the design may be sound but conflict with other federal requirements of which the A/E is unaware. In the example used, a loop cable system was designed; however, with this type of system, the television company can only invoice each building rather than each room desiring cable reception. The design was practical and of sound engineering but conflicted with procurement regulations.

Lessons learned may be reaching the EIC but each EIC is not sharing the information. Nor is it being forwarded to the A/Es. The Construction Division (Code 05) of the EFD frequently promulgates Lessons Learned and other words of wisdom via newsletters to ROICC offices under their respective jurisdiction. This information should be shared with the EICs during, for instance, EFD Quality Circle meetings. Lessons learned should be grouped into checklists or "cook books" and distributed to A/E's under contract. Previous experiences, innovations, and organizational successes and failures need to be shared to eliminate repetition of errors from one project to another.

Complete Documents

To perform quality construction, one must define the criteria to which the work is to conform. Plans and

specifications should be complete and unambiguous. Too much construction money is wasted ultimately due to poor specifications. The engineer of record must be completely responsible for the design. Passing on design requirements to the contractor, such as the design of steel connections to the steel fabricator, must be discontinued. Shop drawing approval should mean more than just meeting the intent of the plans and specifications.

Specifications should be written so they are clearly defined and can be verified. Citing compliance to an entire standard or code only serves to cloud the requirements when only one paragraph of the entire standard is applicable. This may be the affect of today's litigant society and the A/E's conservatism and over-cautiousness. Some construction offices, or even ROICC offices, do not have complete files on all the codes commonly cited. Rather than researching the cited standard, "what we have always done" becomes the new standard. Terminology such as "the materials shall be suitable for the intended usage of the item" or "all welding shall be performed by qualified welders" must not be used.

Remove the overkill. Relevant sections of the appropriate standard or code should be extracted and rewritten into the contract specifications so that anyone can understand what it means and what is expected.

Computer Aided Design

A large portion of design errors and omissions are documentation problems rather than design inadequacies. Putting greater emphasis on the use of computer aided design (CAD) can improve the quality of engineering and design.

CAD is simply the term applied to the process of design when design is supported by computer methods. The process is not a new one as it has been used for several years on mainframe computers and mini-computers. Software is now available for micro-computer systems. The principle behind CAD is the same principle behind a word processor. It does not create, it merely aids the creator in increasing productivity. It is a "design processor".

Advantages of using CAD systems can be found both in the design phase as well as the construction phase of the project. The designer can sit at the CAD workstation and put his ideas on "paper". As changes are made to the design, there is no need to repeat the paper drawing process. Changes (editing) can be made simply to the design at the workstation. Computer models can easily be reconstructed if design conditions change. Notes or comments can be entered on the plans for clarification during the design process and be displayed on the final drawing or maintained in an invisible database.

As the project is reviewed by each engineering discipline (softcopy review), additions/ modifications can easily be made to the design without having to redraft or start over with the drawing. There is less chance of misreading or misinterpretation of revised drawings.

CAD's automatic associative dimensioning capability can reduce problems created by last minute changes in plans. Dimensions related to the changes are automatically updated.

Most CAD programs include some form of layers or levels. This functions the same as using acetate overlays. Disciplines can be displayed and plotted selectively. This has a great advantage when checking for interference or nonconformities between disciplines or for constructability reviews. The probability of a structural beam, a mechanical duct, and an electrical fixture occupying the same physical space is reduced.

Given reliable input, the use of engineering computerized assembly for the checking of interferences and clearances eliminates errors and improves the quality of fit on assemblies. Since all reviewers are working from the same set of engineering data, computational round-off errors as well as personnel hand-offs are minimized.

Another major strength of CAD is in the designing of like parts. Systems that have a parametric design program allow the designer to design one part. With this original

definition in the program library, all the designer has to do is to vary the dimensions on the part to design the remainder of the parts. This can be very useful in designing similar buildings where only site adaptation is necessary.

CAD systems can assist the A/E in figuring cost estimates. Some programs offer the utility of counting the number of times an image is used, i.e. a valve or an electrical outlet. This could greatly reduce the amount of time spent in estimating project costs.

Some CAD software programs automatically check the design against appropriate engineering codes (i.e., ASTM, ACI, etc.) for compliance.

Another advantage of drawings created on a CAD system is the ability to electronically transmit the data by modem to clients for review, changes, and approval. Human errors can be eliminated when incorporating vendor information into the design by transferring the data between computers.

Depending on the bidding process, the construction company can use a CAD workstation to do cost takeoffs in bidding projects. Instead of a set of project plans and specifications on paper, an electro-magnetic set of plans and specifications could be provided. This could help to reduce errors of missed items in the quantity takeoff.

The CAD system can be used to prepare shop drawings for submittals. The same principals/ advantages could apply here as they do for the A/E. Shop drawings could be electro-magnetically transmitted to the A/E for review.

Most projects require "as-built" or record drawings. However, accurate record drawings are not maintained, mainly due to the effort involved. Again, with an electro-magnetic set of plans, changes to the design plans can easily be made as the project progresses and changes to the original design occur. If necessary, as-built changes could be fed back to the A/E to generate as-built calculations and assure no compromise of quality or safety of the design.

The use of CAD in the design arena offers many advantages and increases efficiency and productivity. Designers can create and evaluate more design alternatives in a given time, thereby leading to better designs and higher quality designs. Its use should be emphasized by A/E firms.

Summary

A quality design is paramount to reducing the life cycle cost of the project. The attitude taken should not be "Let the ROICC office fix it, we have a deadline to meet!"

Efforts need to be taken to improve the quality of the design. Special considerations in A/E selection and the 6%

statutory design fee should be eliminated. The proposed two step selection process would provide highly qualified and operationally efficient A/E firms. Proper design reviews, either by in-house personnel or by third party A/E firms, must be conducted. Repetitive errors are unnecessary and costly. Lessons learned from previous construction contracts must be shared with designers. Plans and specifications should be complete, clearly defined, and verifiable. The advantages of computer aided design should be utilized. Efforts must be taken to provide the contractor with quality drawings and specifications.

CHAPTER III

QUALITY IN CONSTRUCTION

A quality set of plans and specifications have been prepared by the A/E. The proposed construction project has been advertised in the CBD. Bids have been received, opened, and evaluated. A contract for the construction of the new facility has been awarded to the lowest, responsive, responsible bidder. How does NAVFAC ensure that quality construction is not lost at the hand of the contractor? Effective quality control during the construction phase is imperative.

Contractor Quality Control

The conception of a formalized quality control system in construction can be traced to the reorganization of the Department of Defense in the early 1960's during the tenure of then Secretary Robert McNamara. His objective was to reduce the DOD budget by requiring DOD manufacturers to assume the responsibility of quality control for their goods. Reevaluation of quality control then extended into Navy construction. In 1969, NAVFAC reappraised its contract inspection procedures, then called the Navy Construction Inspection System (NCIS). [NAVFACINST 4355.6, encl.(4)] It was determined that contractors were not adequately monitoring their workmanship and were relying too heavily on

government inspectors for quality control. Defects in construction which went unnoticed were assumed by the contractor to be acceptable. In March of 1970, NAVFAC issued directives whereby the contractor becomes completely responsible for his work and must engage in active quality control efforts. [NAVFAC message 061842Z March 1970]

Clauses for contractor quality requirements were incorporated into the construction contract General Provisions. Clause 61 (Inspection of Construction, April 1984) states:

> "... The Contractor shall maintain an adequate inspection system and perform such inspection as will ensure that the work called for by this contract conforms to contract requirements. The Contractor shall maintain complete inspection records and make them available to the Government. ..." [FAR 52.246-12]

Contracts having a government estimate over a specified dollar threshold, currently $2 million dollars, and those projects below $2 million dollars that are considered high risk projects, are administered under the Contractor Quality Control (CQC) concept. Under this system, Division 1 of the specifications require the contractor to provide a quality control organization and system to perform inspections and testing to assure compliance with the contract provisions. Testing and inspections are to cover all phases of construction, including off-site fabrication. This system is to provide QA over the contractor's QC. The contractors

CQC plan must be submitted and approved prior to commencement of construction, unless specifically authorized by the Contracting Officer.

The "ramrod" of the contractor's CQC plan is the CQC Representative. He is required to be on the site at all times during progress and shall have the authority necessary to ensure complete compliance with the plans and specifications. He is appointed by an officer of the firm and is to act for the contractor. The CQC Representative may not also serve as, nor be subordinate to, the project superintendent or project manager. This person's sole responsibility is to monitor the quality of construction.

The contractor's CQC organization makes provisions for testing laboratories, consulting engineers, and others to supplement the CQC Representative as necessary. Specific procedures are established by the contractor for the review of all shop drawings, samples, certificates, or other submittals. The objective here is to prevent defects rather than discover them. Inspection procedures are carried out in three phases: preparatory inspection, initial inspection, and follow-up inspection.

Documentation of quality control operations includes daily reports outlining idle personnel and equipment, material deliveries, weather conditions, work accomplished, inspections and tests conducted, results of inspections and

tests, nature of defects found, causes for rejection, proposed remedial action, and corrective actions taken. A submittal status log, listing all the submittals required by the specifications and stating the action required by the contractor or the government, is also maintained.

Some of the objectives or benefits of NAVFAC in utilizing the CQC concept include that it places complete responsibility for compliance with the plans and specifications on the contractor. It requires the contractor to use better management procedures. The contractor becomes liable for intentional deviations; therefore, fewer claims result. It allows more efficient use of Navy inspectors by having the inspector direct his efforts toward the quality control system. The contractor realizes benefits as well including increased control in scheduling and execution of construction projects, and reduced delay and economic savings from shop drawing approval and on-site government inspection.

There are, however, opponents to the CQC concept as it contains many faults and limitations. The system could be equated to the "fox guarding the hen house". Most contractors cannot perform both QC and QA. Results of a survey conducted by Dean, Carr, and Meyer of 27 contractors and 37 A/E firms indicated that when the contractors were asked "Do you think that there would be conflict of interest

if the contractor inspected his own work?", only 11% responded Never (71% Sometimes, 7% Often, and 11% Always). [p. 541] Products of the CQC concept are marginal quality work at a greatly increased price.

It is felt that CQC has been passed on by successes in the manufacturing field, areas where a standardized product is produced. Effective QC/QA measures could be implemented to maintain a quality product. This is important in the manufacturing field as it promotes a good reputation for the company and its product line. Future business is strongly dependent on the reputation of the firm.

On the other hand, in the construction industry, future business is dependent upon being the lowest, responsive, responsible bidder. As long as the contractor has completed his bid package properly, and has not previously been defaulted, if he is the lowest bidder, he is awarded the contract. The contractor's main goals then become to build the project under his estimate, as quickly as possible, with an acceptable or marginal level of quality.

In the same survey by Dean et al., few contractors indicated that they provided a level of quality control above that required by the plans and specifications. For contract awards below $100,000 (1976 dollars), several indicated that the level of quality control was below that required by the plans and specifications. [p. 540]

Contractors, again with the objective of being the lowest bidder, seek the lowest cost CQC Representative that meets the minimum qualifications of the construction contract. Regardless of what the organizational chart or CQC Representative designation letter states, due to the CQC's level of experience, the CQC frequently reports to the job site superintendent, thereby eliminating any QC/QA efforts. The diligent and aggressive CQC Representative may find himself seeking employment elsewhere.

Recognizing the need to raise the quality or competence of the CQC organization, NAVFAC upgraded the CQC concept to Contractor Quality Control Plus (CQC+). This program has been implemented at the Naval Submarine Base, Kings Bay, Georgia and is being considered by EFDs. Under CQC+, submittals must be reviewed and approved by a registered engineer prior to being submitted to the CQC Representative. The CQC Representative is required to be supplemented by competent inspectors in particular areas of construction, i.e. roofing, mechanical systems, or electrical systems. The specifications dictate minimum qualifications of these assistants. Minimum quality control requirements for each technical specification are specifically listed at the end of the respective section.

Third Party Inspection

The CQC+ program has succeeded in raising the competency requirements of reviewers and inspectors. It has provided one organized location in each specification section in which all quality control requirements for that section are clearly identified to the contractor. However, it has not restructured the organization from under the contractor's low bid strategy. Additional costs are incurred by the contractor and are subsequently passed on to the government. The CQC or CQC+ functions should not be delegated to or hired by the contractor but, rather, should be conducted by an independent, third party. This has been the position taken by the organization of National Associated General Contractors (AGC) [Isaak, p. 482] and a recommendation from the ASCE Workshop on Quality in the Constructed Project [Fox, Cornell, p. 154].

Proponents of the CQC concept would argue that the integrity of the contractors' CQC organization is maintained by periodic checks by the Navy inspector and review of submittals by the AROICC or PM. The frequency of government inspections and reviews would be high at the beginning of construction but would lessen as the project progresses, given the CQC organization has demonstrated a high degree of competency. In most instances, the frequency of checking does not diminish and an initial objective of the CQC

concept, that is, a more efficient use of Navy inspectors, is not being met.

Placing the responsibilities of the CQC Representative under the purview of a third party would remove the "fox from the hen house". It is recommended that the third party be the A/E firm that designed the project. In the survey of Dean et al., the A/Es and the majority of the contractors felt that the A/E's representative should be responsible for the inspection and quality control in contracts with a one year warranty clause. [p. 538] The CQC Representative, as well as any supplemental inspectors, would be hired by the A/E and integrated into the contractors' CQC organization. In doing so, a possible conflict of interest would be eliminated.

The A/E's involvement during the construction phase has essentially been limited to project stopping problems. Yet, the A/E assumes liability for his design. Involving the A/E as the CQC Representative gives the firm a voice in construction related problems. He can better assure that the degree of quality incorporated in the constructed facility is the same as that placed in the design.

Extended Warranty

An alternative to using a third party would be to require the contractor to warrant his work for more than one

year. Warranties are a form of assurance that products are fit for use or, failing this, that the user will receive some extent of compensation. Warranties constitute a system for reducing user costs of poor quality. Results from the survey conducted by Dean et al. indicated that 27% of the A/Es responding could foresee allowing the contractor full responsibility for QC/QA provided the warranty period was extended to three years. Forty-four percent of the contractors responding to the survey would prefer the option to exercise full responsibility for QC/QA and would provide a one and a half year extended warranty. [p. 541, 544]

Design Changes

The introduction of design changes during the construction phase is disruptive to the project. Delays caused by the decision or approval process for customer requested changes can be quite lengthy. Should the AROICC or PM stop the contractor from working in the affected area until approval is given for the change or should he permit the contractor to continue and demolish when approval is finally received? In either case, the contractor's schedule is delayed, quality of the facility is compromised, and the cost of the project has risen to an amount disproportionate to the changed work.

As an example, approximately 35% through the construction phase of a Base Civil Engineer Facility, the need was identified for a Base-U-Fix-It Shop to be incorporated into the project. Ultimate approval of the customer requested change was almost certain; however, the formalized procedure for requesting the change, redesign, and authorizing the change took several months. In the meantime, the contractor proceeded with his contract. When approval was finally received and a change order was negotiated, additional time and money was required to demolish some recent construction.

Every effort must be taken to severely restrict customer requested change orders. Project requirements must be identified early in the design phase and design freeze dates must be established and enforced. The contractor must be provided complete plans and specifications in order to properly fulfill his contract. Disruptions only cause schedule slippage, increased costs, and most important, possible compromise in the quality of the facility.

Inspector Qualifications

Inspection is a vital part of quality control. Whether the individual is filling the position of the government inspector, be it a civil service employee (GS-8/9) or via an A/E Inspection Services Contract (Title II), or CQC

Representative, he retains a great deal of responsibility for the quality of the project. Yet, although the responsibility of each is nearly identical, experience requirements are not standardized.

Candidates for the position of GS-8/9 inspector must have completed a minimum of two years general experience and four years of specialized experience. General experience is that which provides familiarity with construction work or which provides knowledge that would be helpful in reading plans and specifications, making measurements, or testing. Specialized experience includes a knowledge of a sufficiently broad variety of trade and craft processes to recognize acceptable construction practices, general construction inspection practices and procedures, safety requirements, and an ability to work with contractors. [U.S Civil Service Commission, p. 1]

The Title II Inspector is required to be a U.S. citizen, capable of reading contract drawings and specifications, and have a minimum of three years experience as construction inspectors on construction projects or other similar experience. [Contract N62467-84-C-0596, encl(1), p. 1]

SOUTHDIV requires the CQC Representative to have the following minimum qualifications:

> "(1) Shall be a graduate engineer or architect with at least three years of acceptable field

> experience and shall meet the requirements of "(3)" below, or
>
> (2) Shall have at least a high school education and shall have functioned for not less than five years as an inspector, project superintendent or project manager on both utilities and building construction for Government or private agency (or agencies), and shall meet the requirements of "(3)" below.
>
> (3) Shall be familiar with the generally accepted construction practices, applicable codes and standards, and materials that will be applied to and incorporated in this project." [Contract N62467-83-C-0064, section 01400-1]

Minimum qualifications may vary between EFDs.

The CQC Representative under CQC+ is required to be a graduate engineer or architect with a minimum of one year experience in quality control or have a minimum of three years construction experience of similar type construction to the contract including one year experience in quality control. [Contract N68248-86-C-6018, section 01400-4]

The Title II inspector is contracted under A/E services to supplement the inspector work force at the ROICC office. The CQC Representative does not replace the government inspector but performs nearly identical functions. Yet, the minimum qualifications for these people are less stringent than for the government inspector. Qualifications for government inspector, Title II inspector, and CQC

Representative should be standardized and be written so as to require higher levels of specialized experience.

Inspector Checklists

To assist their field construction engineers, Owens-Corning Fiberglas Corporation, in conjunction with Texas A&M University, has recently developed the Construction Quality Field Checklists, a 3 1/4" by 6 1/2" booklet containing quality assurance questions organized by construction discipline. The questions are intended to remind experienced field construction engineers of issues which must be addressed in each discipline. The questions are also intended to instruct field engineers inexperienced in a given discipline (for example, an electrical engineer who may be required to oversee concrete foundation work) in things to look for to assure quality work. [D.R. Eberts, personal communication, 14 May 1986]

The Field Checklist was designed to fit into the engineer's hip pocket. In this way, it is readily available without encumbering him with books or standards. Such an idea, oriented toward NAVFAC construction, would greatly assist the government inspector and do much to improve quality assurance.

Summary

The objective of any quality control program is to verify that the quality of the finished product meets the designed level of quality. The CQC concept is the Navy's method of placing the responsibility for quality construction and verification on the contractor. However, the QC/QA process should be provided without any bias or self-interest. It has been shown that this may not always be the case for the CQC program. Quality assurance should be conducted by a third party. The A/E for the project has an avid interest in ensuring that the quality of his design is met. The scope of work in the engineering services contract should include Title II inspection for contracts where the construction estimate is above $2 million dollars and those projects below $2 million dollars that are considered high risk. This inspector will serve as the CQC Representative and will be integrated into the contractor's QC organization.

Design freeze dates should be set and adhered to as customer requested change orders disrupt the construction schedule, escalate project cost unnecessarily, and compromise quality of the facility.

Persons charged with QA (GS-8/9 Inspector, Title II Inspector, or CQC Representative) should meet a standard set

of minimum requirements. These requirements should emphasize specialized experience.

It is recommended that NAVFAC develop field checklists similar to that developed by Owens-Corning Fiberglas Corporation to assist government inspectors to maintain high quality standards in their construction projects.

CHAPTER IV

QUALITY PERCEIVED

Quality management does not end at the final inspection of the facility. Quality is also a measure of a facility's fitness for use by the client command. How does the client command perceive its new facility? Have its objectives been met? The user's views on quality can differ considerably from those held by the parties actively involved in design and construction.

There presently is no formalized technique to solicit and accomodate user input. Such a system is important to providing the user with a quality facility as it would help to identify weaknesses of the system and improper practices for ultimate correction. It would also be used to identify the user's relative importance of various facility qualities, identify user's problems about which they do not complain but which NAVFAC might nevertheless be able to remedy, and solicit user's ideas that NAVFAC might be able to utilize for their (the user's) future benefit.

A questionnaire should be developed to solicit input from the user command. This would be forwarded to the user command upon completion of the facility and acceptance by the user command. Figure 3 is offered to meet this necessity. Questions on the form are directed at common complaints from previous projects. Information obtained may

be used by the ROICC or EFD to improve the system and provide future customers with better quality service and products.

DATE:

FROM: RESIDENT OFFICER IN CHARGE OF CONSTRUCTION, (Location)

TO: (User Command)

SUBJ: CONTRACT N_____-__-C-____; (Contract Name)

In an effort to improve the quality of the product provided, your response to the questions below would be sincerely appreciated. Please identify possible problems about which you would not normally complain but which NAVFAC might nevertheless be able to remedy. Please provide ideas that NAVFAC might be able to utilize for your future benefit. The success of a quality management program is dependent on your earnest input.

(signature)
ROICC

1. Did the design conform to the command's mission requirements?

2. Was the facility designed with ease of maintainability in mind?

3. Does the facility present an aesthetically pleasing appearance?

4. Does the appearance of the facility complement the appearance or "theme" of the base?

5. Were comprehensive operation and maintenance documentation provided, if applicable?

6. If applicable, was training provided for operations and maintenance personnel?

Figure 3 - User Quality Evaluation Form (front)

7. Was the command kept appraised of progress and/or problems of the project via status reports and/or briefings?

8. Did effective communication exist with the ROICC?

9. Does the finished product represent quality workmanship?

10. Did the command conduct design reviews?

11. If the answer to #10 is yes, were answers received from the designer for your design review comments? Was the designer receptive to the command's ideas?

12. Was the command present at the preconstruction conference? Was it a beneficial meeting?

13. Did the command participate at the pre-final inspection? Was the ROICC receptive to the command's comments?

14. Was the command represented at the final inspection?

ADDITIONAL REMARKS:

(signature)

Figure 3 - User Quality Evaluation Form (obverse)

CHAPTER V

CONCLUSION

Quality must be the primary consideration throughout the life of a NAVFAC construction project. Quality must be placed above meeting time schedules or being under budget. By placing the primary emphasis on quality, the benefits of timely completion and cost effective construction projects will result.

Improvements in the Design and Construction Phases of NAVFAC construction projects are needed to raise the quality of each respective phase. This paper has highlighted some perceived problems in each phase and offered alternatives to improve the process. Quality must be stressed in the selection of the A/E, the preparation of the plans and specifications, the performance of the contractor, and the perception of the project by the client command.

NAVFAC has also identified deficiencies in the construction process and has tasked each EFD to develop Quality Assurance Improvement Plans. However, due to hiring restrictions, workload, lack of funds, or lack of resources, the EFD's goals will not be met. Until proper priorities are established and appropriate resourses are provided, most EFDs are only giving "lip service" to improving quality.

The pursuit of quality has not yet received the emphasis it requires. Only by promoting total quality management can NAVFAC be synonymous with quality construction!

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